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Guglielmo Marconi 1874-1937

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Cover : Marconi's magnetic detector.

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Guglielmo Marconi 1874-1937

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London

1 Marconi as a child, with his mother and his elder brother, Alfonso

Guglielmo Marconi:
born April 25th 1874, died July 20th 1937

Early experiments

In the autumn of 1894, at the age of 20, Guglielmo Marconi began experimenting in the attics of his parents' large villa near Bologna in Italy. His object was to achieve wire-less telegraphy by means of 'Hertzian Waves'—to use, in fact, a phenomenon that only a few physicists fully understood, for a purpose lying within the province of qualified electrical engineers. To all appearances, it was a project for which he was hopelessly ill-qualified.

Guglielmo's mother had been born Annie Jameson, of the Scottish/Irish family of brewers and distillers. Though she had run away from home to marry Guiseppe Marconi, a wealthy widower, she contrived to spend much of her time in places more congenial to her than his estate in the country, wintering in Florence or Leghorn (with their colonies of British residents), taking the waters at the spa of Porretta, and visiting friends and relatives in England. Guglielmo accompanied his mother on her travels, and his education suffered accordingly. He had private tuition during his periods at home, but this left him quite unprepared for the rigours of school, which he first encountered in Florence at the age of twelve. A spell at the Technical Institute of Leghorn was more successful; in particular, his liking and aptitude for physics were such that his mother arranged for him to have additional instruction from a private tutor, and he acquired a valuable grasp of the rudiments of the subject. Nevertheless, he dropped out of full-time education without gaining the qualifications needed for entry to either of the institutions that would have satisfied his father's ambitions for him: the University of Bologna or the Naval Academy at Leghorn.

Relations between father and son were further poisoned by the 'scientific experiments' that Guglielmo conducted at home. These were no doubt valuable in developing his experimental skill, but most of them were manifestly trivial, and they simply confirmed Guiseppe's conviction that he was harbouring a dilettante.

Annie Marconi, however, never wavered in her support for her son. One of the family's neighbours, Professor Augusto Righi, of the University of Bologna, was a noted physicist, and Annie prevailed upon him to act as Guglielmo's adviser and to grant him such privileges as the loan of books from the university's library. It was through this contact that the young man's general interest in electricity became focussed upon Hertzian waves.

These were, of course, what we now call radio waves, but at that time were still named after Heinrich Hertz, who had carried out a classic series of experiments in 1887/8, proving that such waves existed and establishing their properties. Hertz's work was of very great theoretical significance,

and was studied by many physicists, some of whom (including Righi) repeated and extended his experiments. Yet by 1894 no one had sought to apply the waves to communication although, paradoxically, William Preece, Engineer-in-Chief of the British Post Office, was attempting to achieve 'wire-less' telegraphy (by means of inductive coupling between long, parallel circuits) with no thought of using Hertzian waves for the purpose.

Hertz died in January 1894, and it was through reading a commemorative article on his work by Professor Righi that Marconi's idea came to him, suddenly and obsessively. He was away from home on holiday at the time, and the enforced delay before he could begin to carry out experiments served only to increase his excitement. When he returned home, his mother put at his disposal two attics, empty save for trays of silkworms, and he set to work. Professor Righi pointed out his presumption in tackling work that was properly the province of a trained scientist, but Guglielmo was deaf to his advice.

He began by repeating Hertz's experiments, in which the waves, radiated by action of an electric spark, were detected by their ability to induce a further, very feeble, spark across a tiny gap in a receiving circuit. Like Hertz, he achieved ranges of only a few metres. He then incorporated a form of detector that had first been used by Oliver Lodge, who had named it the 'coherer'. In its most common form this consisted of a glass tube containing metallic filings, closed by an electrode at each end. Normally the filings provided only a very high-resistance electrical path between the electrodes, to which the receiving aerial was connected, but when the aerial picked up a signal, the weak high-frequency voltage across the electrodes made the filings 'cohere', and their resistance fell to a low value. This change could be registered by means of a battery and bell in series with the coherer, whilst the stroke of the bell could be made to give the device a slight blow, to 'de-cohere' it (i.e. to restore it to its high-resistance condition). So long as the waves persisted, therefore, the receiver indicated the fact by a rapid alternation of coherence and de-coherence.

Though the sensitivity of the coherer was a crucial factor in the range that could be achieved, its operation was not at all well understood. Marconi therefore set about improving it by trial and error, of which he was a superb exponent; he was exceptionally persistent, continuing his experiments without regard for food or sleep, and he was keenly observant. His experiments led him to a greatly improved coherer in which a fine powder consisting of 95% nickel filings and 5% silver filings was enclosed in an evacuated tube.

By such improvements of existing techniques, Marconi was able to increase the range of communication to the point at which it was necessary to transfer operations to the garden, and it was here, in September 1895, that he made a crucial discovery. Up to that time, the transmitter's spark had always been arranged to stimulate small circuits of low capacity, giving wavelengths that were typically a metre or less. Marconi now began to

experiment with slabs of sheet-iron connected to each side of the spark gap. Recalling the episode many years later, he stated that he did this with the deliberate intention of obtaining longer waves, which would pass round obstacles more easily. Then, by chance, he set one slab on the ground and held the other high in the air, and was surprised to find a large increase in the strength of the received signal. He thus discovered the combination of a vertical conductor and an earth connection that has remained the basic aerial configuration for the lower end of the radio-frequency spectrum. By using this arrangement at the receiver too, he was able to increase his range dramatically, to about a kilometre.

By this time, Guiseppe had been persuaded to give the venture his financial support, and Guglielmo's chief assistant, his devoted elder brother Alfonso, was able to enlist the help of his father's employees to help him in his task of manning the receiver. With Guglielmo operating the transmitter at the house, the receiver was taken ever further into the fields, and success signalled back by waving a pole from which a white handkerchief fluttered. Then came the crucial test of sending the receiving party out of sight, over the hill that lay behind the house, armed with a hunting rifle for signalling back. When Guglielmo began to operate the transmitting

2 Marconi shortly after he came to England in 1896

key, he had the satisfaction of hearing a distant shot echoing down the valley.

With a maximum range of over two kilometres achieved, the Marconi family judged that it was time to approach prospective users, with a view to securing their support for further development. Unfortunately they chose to offer Guglielmo's findings to the Ministry of Posts and Telegraphs, who politely declined, being understandably indifferent to a technique that, for their purposes, offered no advantages over the well-established technology of conventional telegraphy. Had the family approached the Navy, it is likely that they would have received a more encouraging response; considered as a potential means of communicating with fighting ships, wireless telegraphy had only to offer some advantage over a siren, flags, or a flashing lamp in order to be of interest.

The move to England; official demonstrations

Annie Marconi had already considered taking Guglielmo to England to continue his work, and had received encouragement from her relatives there; since marine applications would obviously be important, it made good sense to develop and promote wireless telegraphy in the world's leading maritime country. Now, following the snub from the Italian authorities, the idea was revived, and in February 1896 mother and son set out for London. Guglielmo carried with him on the journey a black box containing his apparatus, and had the chagrin of seeing its contents broken in the course of examination by British Customs officials, whose suspicious reactions to the unfamiliar nature of the apparatus were aggravated by the young man's inability to provide satisfactory answers to their questions about it.

They were met in London by Marconi's cousin, Henry Jameson-Davis, who was (as he later recalled) 'in considerable practice as an engineer', and was therefore well placed to further Guglielmo's interests. Marconi at once embarked on drawing up a patent specification to protect his invention, and in June 1896 filed his application for what was to be the world's first radio patent. Meanwhile, Jameson-Davis had enlisted the interest of a friend A. A. Campbell Swinton, who was a successful electrical engineer. After witnessing a demonstration, Campbell Swinton gave Marconi a letter of introduction to William Preece, Engineer-in-Chief of the Post Office; Preece, it will be recalled, was himself experimenting with wireless telegraphy, though he was not using radio waves.

On the strength of preliminary demonstrations in his laboratory, Preece invited Marconi to give his first formal demonstration to Post Office officials, and this took place in London in July 1896. The two stations were situated on the roofs of two Post Office buildings in the City. Though the range was only a few hundred metres, the successful transmission of signals despite the presence of intervening buildings greatly impressed the audience, and Preece asked for further demonstrations, at greater range.

These took place on Salisbury Plain at the beginning of September, and now Post Office observers were joined by representatives of the War Office and the Admiralty. Notwithstanding the success he had achieved in Italy with elevated aerials, Marconi chose to conduct many of the tests with apparatus in which the transmitting and receiving circuits were each placed at the focus of a parabolic, copper reflector. The total lack of secrecy in transmission by radio was an obvious disadvantage, especially in military applications, and the directional properties that Marconi showed to be imparted by the reflectors gave promise of secrecy by means of precisely beamed transmission. With the technology of 1896, however, the range was limited to about two and a half kilometres, while the use of very short waves carried the penalty of requiring transmitter and receiver to be within sight of each other. Tests with an elevated aerial, giving a much longer wavelength, were hampered by the fact that the poles used were only three metres long, and the range achieved was only half a kilometre. Nevertheless, observers were favourably impressed, and the Post Office scientist officially reporting the tests concluded that '. . . the general result of the experiments very conclusively shows that the whole system is well worthy of further consideration and trial'. A second series of tests on Salisbury Plain was staged six months later, when kites and balloons were used to elevate aerials to heights in excess of forty metres. This gave reliable communication up to a range of seven kilometres; no experiments were carried out with reflectors.

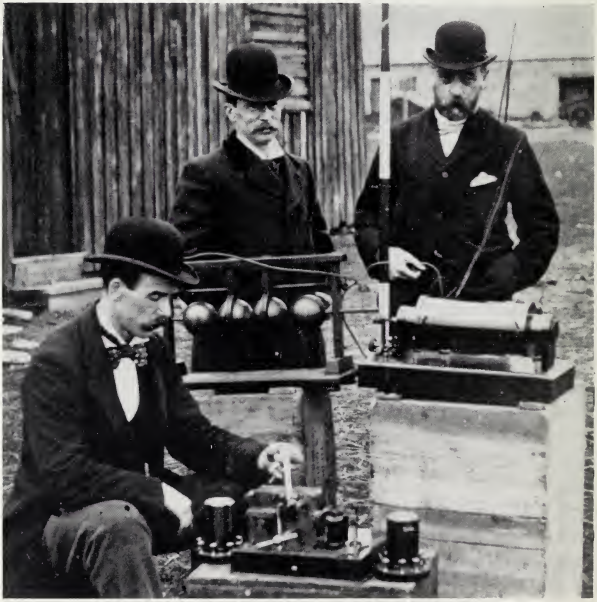
Marconi's apparatus was demonstrated to the public and the Press for the first time in December 1896. The occasion was a lecture in London by William Preece, at which Marconi moved around the auditorium carrying a receiver that incorporated an electric bell; whenever Preece, on the platform, pressed the transmitting key, the bell rang. As an additional touch of showmanship, both transmitter and receiver were housed in black boxes.

Our own familiarity with radio communication makes it difficult for us to imagine the astonishment produced in lay observers by such demonstrations. Marconi soon became a celebrity; his courtesy and his blend of modesty and self-confidence ensured that he was presented sympathetically by the Press. However, reporters tended to credit him with having invented or discovered everything to do with wireless telegraphy, and this generated resentment in the scientific community. Understandably, the person most deeply offended was Professor Oliver Lodge, who had come close to anticipating Hertz in the discovery of radio waves, had first developed the coherer as a practical detector, and had in fact demonstrated the transmission of Morse signals over a distance of sixty metres before Marconi had even begun his first experiments. Lodge, however, had regarded this feat as no more than a piece of showmanship, and had not followed it up in any way.

But now Lodge realised that one of his early demonstrations of high-frequency phenomena, dating from 1889, was relevant to a major problem

confronting Marconi. At that time Marconi's equipment was devoid of any form of tuning; the oscillations in the transmitting circuit died away too rapidly to acquire a well-defined frequency, whilst the receiving circuit responded indiscriminately to a wide range of frequencies. Thus mutual interference made it impracticable for two transmitters to operate simultaneously in the same area.

Lodge had shown that when a 'Leyden jar' capacitor was discharged through a loop of wire, the resulting oscillations produced sparking in a similar circuit nearby, but only when the two circuits were the same size and hence were resonant at the same frequency. This experiment was not directly applicable to wireless telegraphy. As Lodge himself had pointed out at the time, his transmitting circuit produced well-sustained oscillations only because it was losing very little energy by radiation—because, in fact, it was an inefficient transmitter; similar considerations applied to his receiving circuit. But with his sound theoretical knowledge Lodge was



3 Post Office engineers examining Marconi's apparatus during the Bristol Channel tests, 1897

nevertheless now able to devise simple circuits in which a useful balance was struck between the conflicting demands of efficient aerials and effective tuning. The patents in which he embodied these ideas were to prove an embarrassment to the Marconi Company many years later.

The summer of 1897 began with another successful demonstration in co-operation with the Post Office. An obvious application for wireless telegraphy lay in the bridging of narrow stretches of water, as an alternative to submarine cables, which were expensive and, in busy seaways, extremely vulnerable; at Plymouth one particular cable was severed four times in three months. It was, therefore, important to establish that radio waves could in fact be transmitted over water, and Preece arranged for tests to be made in the Bristol Channel, in which Marconi's system was compared with his own 'induction' system. Both spanned the five kilometres to an offshore island, but Marconi's apparatus, much less cumbersome than Preece's, also spanned the fourteen kilometres of the whole channel.

The Marconi Company

Notwithstanding these successes, Marconi's position at this time was not altogether a happy one. He had no official standing and he was still living at his family's expense. Fruitful though his collaboration with Preece had been, it offered no prospect of a career, nor did the co-operation he received from the Post Office and the War Office provide for the sustained research that he knew he must undertake if he was to maintain his pre-eminence.

There was an indication of the insecure foundations upon which his fame rested when the specification of his first patent was published on March 2nd 1897. The influential journal, *The Electrician*, greeted it with derision, pointing out how many of its nineteen claims had been anticipated by Lodge, and declaring 'If this patent be upheld in the courts of law it will be seen that it is . . . easy for an eminent patent-counsel to compile a valid patent from the publicly described and exhibited products of another man's brain'.

Nevertheless, the publicity that Marconi received was predominantly favourable, and his cousin Henry Jameson-Davis, who had continued to act as his adviser, had no difficulty in securing offers of financial backing. Though Guglielmo shared the family's wish to establish a company, he was aware that this would jeopardise the privileged position he enjoyed through Preece's sponsorship, and he hung back until Jameson-Davis warned him that potential backers would not wait much longer.

A company was registered, on July 20th 1897, with the title 'The Wireless Telegraph and Signal Company Limited'. Marconi's name was excluded at his own wish, though the title was to be changed in 1900 to 'Marconi's Wireless Telegraph Company Limited'. In return for exclusive rights to all his patents, Marconi received £15,000 (less certain expenses) in cash, as well as 60,000 of the Company's 100,000 one-pound shares. As he feared, the Post Office reacted unfavourably, and he was actually excluded

4 Marconi demonstrating to the Italian Navy in 1897

from a series of forthcoming tests at Dover. When the tests produced disappointing results, however, he was belatedly invited to participate.

At the time the Company was formed, Marconi was temporarily back in Italy, which he had left as a totally unknown youth less than eighteen months before. Now he was returning, at the invitation of the Minister of the Navy, as a man of some importance; a dinner was given in his honour and he was presented to the King and Queen. His demonstrations to the Italian Navy were the first in which he had transmitted to a ship at sea, and at times signals were received beyond the horizon.

With the formation of the Company, Marconi could establish permanent premises for experimental work. He chose two coastal sites within range of each other, so that he could investigate transmission between them as well as communication with ships. One site was at the Needles Hotel, Alum Bay, at the westernmost tip of the Isle of Wight; the other, after a brief spell at a hotel in Bournemouth, was established at the Haven Hotel, near Poole, almost thirty kilometres from Alum Bay.

Marconi was now recruiting technical staff, mostly from Technical Schools rather than Universities. He had a gift for inspiring personal loyalty in his staff, and many of these early recruits spent a lifetime in his service. Though he drove them hard, he was equally unsparing of himself; his manner was courteous and unassuming, but he did not encourage undue familiarity. One member of the staff who was not chosen for his academic attainment was George Kemp, an ex-Petty Officer who had been one of

Preece's laboratory assistants. From the outset of Marconi's association with the Post Office, Kemp had been detailed to act as his personal assistant, and had become such a devoted and valuable factotum that it was unthinkable for the connection to be severed.

By November 1897 Marconi had installed a mast nearly forty metres high outside the Needles Hotel and was ready to begin tests of reception at sea. A small tug-boat was rented, and steamed to and fro in the Solent for several weeks, while reception conditions were recorded. Appalling weather tossed the vessel about and the cabin housing the equipment was at times knee-deep in water. The fact that communication was nevertheless achieved up to a range of almost thirty kilometres helped to dispel any impression that because wireless telegraphy involved fragile equipment it required laboratory conditions.

During 1898, Marconi and his engineers contrived to mount numerous operational exercises, thereby widening the application of wireless telegraphy and stimulating public interest in it. At the same time they pressed on behind the scenes with technical developments.

Some of these exercises were purely for publicity. A link was established, for example, between Osborne House, Queen Victoria's residence on the Isle of Wight, and the Royal Yacht lying nearby off Cowes, so that the Queen might receive bulletins on the progress of the Prince of Wales, convalescent after a fall. It is an indication of Marconi's self-confidence that, while walking through the grounds of Osborne House to inspect his equipment, he refused a gardener's request that he should change his route to avoid a possible violation of the Queen's privacy; when told of the incident, she is reported to have ordered 'Get another electrician!' It is only fair to add that, when informed 'Alas, your Majesty, England has no Marconi', the Queen relented and granted the young trespasser an audience.

Several of the operations showed that wireless telegraphy could already offer a valuable service in marine applications notwithstanding its limited range. Lloyds had found, for example, that when ships passing one of their observation stations on the Irish coast were hidden by fog, they could often still be seen from a lighthouse on an offshore island. At the request of Lloyds' Committee, Marconi had a transmitter installed at the lighthouse, which successfully signalled sightings to a mainland telegraph office twelve kilometres distant.

Marconi offered Trinity House an experimental installation on the East Goodwin lightship, which they accepted, and on December 19th 1898 Kemp was put aboard with equipment and a week's provisions. He readily established communication with a station at South Foreland, nineteen kilometres away, despite foul weather. The weather became even worse, and the unfortunate Kemp could not be taken off the ship for twenty-two days. Though ill and half-starved he managed to keep the link in operation and even to teach the lightshipmen how to use it. Kemp's diary suggests that Marconi, relatively snug at the shore station, was indifferent to his

plight, and reveals that Kemp felt a resentment quite at variance with his usual attitude of uncritical devotion. The installation was kept in operation for over a year, and amply proved its value by enabling a number of emergencies to be reported.

Enormous publicity attended the use of wireless telegraphy to report the 1898 Kingstown Regatta, for a Dublin newspaper. Marconi, operating a transmitter in a tug following the races, was able to relay the moment-by-moment situation to the shore, from ranges of fifteen kilometres and upwards.

Other episodes symbolised future developments, as when Lord Kelvin, witnessing a routine demonstration of transmission from the Isle of Wight to the mainland, sent over messages to be forwarded to friends, and insisted on paying a shilling for each message; this was the first commercial use of wireless telegraphy, and, as both he and Marconi knew, a violation of the Post Office's monopoly of inland communication. Marconi's final achievement during 1898 was to open the world's first radio factory, in a converted furniture warehouse at Chelmsford, Essex, though no substantial orders were to come in until well over a year later.

Technical advances

During 1899 range was increased very considerably. In the spring, a link was demonstrated between the existing station at South Foreland and a station erected at Wimereux, near Boulogne, about fifty kilometres away. Predictably, this first achievement of international wireless telegraphy received a great deal of publicity, and in September the opportunity was taken to harvest a second crop by exploiting the happy coincidence that the British Association was meeting at Dover just when a comparable French body was meeting in Boulogne. A temporary mast was rigged at Dover Town Hall, and ceremonial messages duly exchanged with Wimereux. But during this operation, it was found that the signals from Wimereux were also being received reliably at Chelmsford, over 130 kilometres away.

This was a result of the highest significance. At that time it was not known that radio waves were bent by ionized layers in the earth's upper atmosphere, so scientists assumed that the waves could never reach beyond the horizon; the phenomenon of diffraction, whereby a wave wraps round an obstacle comparable in size with its own wavelength, can account for reception behind a hill but gives only a negligible effect for an obstacle as large as the earth. Marconi had never allowed himself to accept this conclusion, which implied a very restricted future for wireless telegraphy, but his opposition had been based on faith (possibly aided by unwarranted hopes of diffraction) rather than on evidence. Now he had accomplished, with masts only forty-five metres high, a range that would have required masts at least three hundred metres high had propagation been restricted to 'line of sight'.

In July 1899, three British warships were equipped with Marconi appar-

atus for the summer manoeuvres. The Royal Navy was fortunate in having in its service an officer, Captain Henry Jackson, who was himself a pioneer of wireless telegraphy. Jackson had represented the Admiralty in their earliest contacts with Marconi, and the two men collaborated fruitfully and amicably over several years establishing wireless telegraphy in the Navy's ships. Although the outcome of the manoeuvres was not directly affected by the use of radio, the fact that ranges of nearly a hundred kilometres were achieved under operational conditions made it quite clear that radio communication was essential for any modern battle fleet. But though the Navy were anxious to buy equipment, the Admiralty and the Company could not agree on terms, and by the end of the year the situation had deteriorated to the point where the Admiralty invoked their right to manufacture equipment needed for national defence, irrespective of patent considerations. However, when the equipment was made, it was found to be inferior to Marconi's; moreover, it was untuned, and Marconi's were known to be on the point of producing tuned ('syntonic') apparatus. In the face of these facts, the Admiralty was obliged to yield to the Company's demand for a royalty of £100 per set per annum, which they had previously dismissed as 'preposterous' and 'prohibitive', and placed an order for thirty-two sets; they subsequently had fifty copies of the Marconi set made by Ediswan's and refused to pay any royalties at all on them.

The improvement in the range of communication achieved by the Marconi Company was primarily due to the introduction of radio-frequency transformers, known as 'jiggers', into the circuits of the transmitters and receivers. In the transmitter, the spark-gap discharged a capacitor of high value (and hence high energy-storage) through the primary of the transformer, forming a closed circuit capable of sustained oscillation; the aerial was connected to the secondary. In the receiver, the transformer enabled the aerial to deliver a higher voltage to the high-impedance load provided by the coherer. The developments were patented in Marconi's name, though it is impossible to say how far the credit for them belongs to him personally and how far to his engineers. It is on record, however, that many hundreds of jiggers were tried out before optimal designs were reached, suggesting that Marconi's trial and error methods were still dominant.

The increased range of transmission heightened the problem of interference between stations, and shortly after his success in the British naval manoeuvres Marconi had the chagrin, during trials conducted for the American Navy, of being unable to satisfy their requirement of maintaining communication between two warships while a shore station was also transmitting. This feat was probably within the capability of his latest apparatus, but Marconi was not prepared to reveal this apparatus until it was protected by patents.

The introduction of 'jiggers' had not only improved electrical efficiency but had produced circuit configurations that required relatively little modification to give a so-called 'syntonic' system—that is, a system of the

type that we now take for granted, in which the transmitter radiates a well-defined frequency, whilst the receiver can be tuned to give maximum response at that frequency.

Marconi's techniques for achieving a syntonic system were incorporated in his patent no. 7777, of 1900 (known as the 'four sevens' patent) which was later to be the subject of much litigation; it was virtually impossible for competitors to avoid infringement, although arguably the patent itself was anticipated by Lodge's patents.

The transatlantic venture

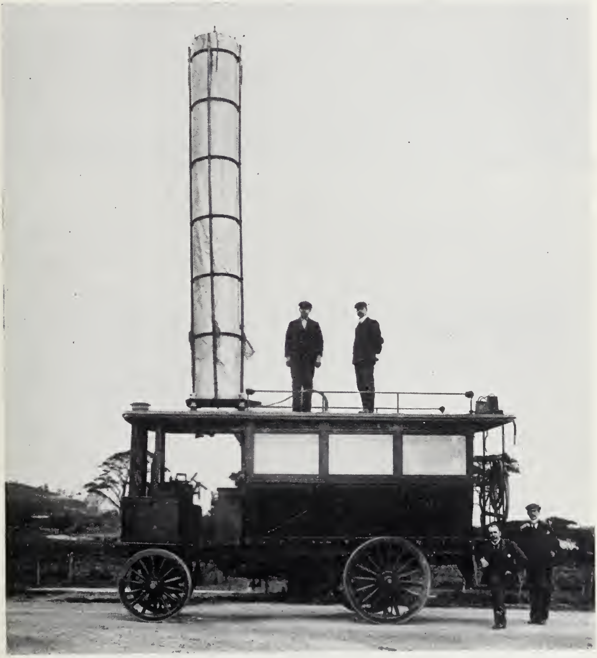
By 1900, the Marconi Company was able to offer a system that was, within limits, technically viable. Its financial position, however, was less healthy; though its one-pound shares had on occasions been quoted at six pounds, virtually no orders had been received. And on all sides the bubble was being taken nearer to bursting point by the need to make further investments without the prospect of any immediate return. Thus, the Company was by this time constantly being involved in the expense of conducting demonstrations and negotiations in all parts of the world and though these hardly ever led to any orders it would have been dangerous not to pursue

5 Marconi and Kemp, about 1901, with apparatus including (right) the induction coil supplying high-voltage power for the transmitter and (centre left) the Morse inker recording the output of the coherer receiver

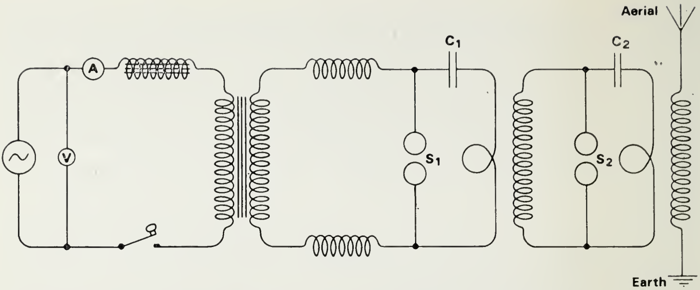
overseas business in this way, for competition from German and American companies was beginning to make itself felt. Again, the range of wireless telegraphy was now sufficient to be of some value to merchant shipping, and on April 25th 1900 (Marconi's twenty-sixth birthday) the Marconi International Marine Communication Company Limited was founded to exploit this market. But before ship owners could be expected to equip their vessels, the Company had to establish, at its own expense, a network of shore stations to serve them.

It was at this critical time, when financial restraint was so necessary, that Marconi announced to his shocked fellow directors that he proposed to build two stations of unprecedented power in an attempt to communicate across the Atlantic Ocean.

This objective appeared to be sheer folly. The range was more than



6 *An experimental mobile station, 1901; the aerial was hinged back to lie horizontally when the vehicle was on the move. Marconi and Professor Fleming can be seen at the rear of the vehicle*

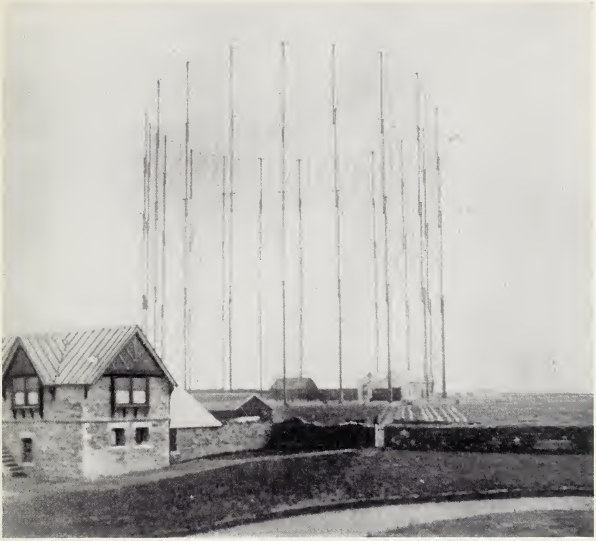


7 Circuit diagram of the transmitter used at Poldhu for the 1901 transatlantic experiments. The alternator charges the capacitor C_1 through a circuit resonant at the alternator frequency. Spark-gap S_1 then discharges C_1 and charges C_2, through circuits resonant at an intermediate frequency. Finally, S_2 discharges C_2 through a circuit resonant at the radiated frequency, to which the aerial circuit is also tuned

twenty times the best previously achieved, and there was a mountain of water over two hundred kilometres high between transmitter and receiver. Marconi argued, however, that with transmission beyond the horizon already achieved, the range would be limited only by the power of the transmitter; hitherto, transmitters had been modest affairs of induction coils and accumulators, so there was plenty of scope for expansion. And if the attempt were successful, the way would be open for operating a commercial transatlantic service that could undercut the rates charged by the operators of submarine cables.

Reluctantly, the Company's board agreed to the project. Sites were selected at Poldhu, in Cornwall, and at Cape Cod, Massachusetts; the remoteness of Poldhu was regarded as an advantage, since it was feared that a high-power station would interfere with domestic electric lighting. The transmitters were designed by Professor Ambrose Fleming, a leading authority on heavy electrical engineering, whom Marconi had appointed Scientific Adviser to the Company in 1899. Fleming duly produced an ingenious circuit with two spark-gaps operating in cascade at different frequencies, powered by a twenty-five-kilowatt alternator which in turn was driven by a thirty-two-horsepower oil engine. The aerial consisted of an inverted cone of wires, sixty-one metres high, supported by a ring of twenty masts. A station built near Poldhu, primarily to test its transmissions, picked up signals from a station on the Isle of Wight at a range of nearly three hundred kilometres.

In March 1901 one of Marconi's assistants, R. N. Vyvyan, was sent over to America to build the second high-power station. Before leaving, he criticised the design of the Poldhu mast system, which he was under orders



8, 9 The aerial system at Poldhu before and after the gale of September 17th 1901

to copy; though each mast was stayed against radial movement, its only tangential constraint came from horizontal wires tying it to its neighbours. Vyvyan's objection was over-ruled, and no heed was taken of his subsequent warning, in August, that the aerial he had built at Cape Cod was dangerously distorted by no more than a stiff breeze.

On September 17th a heavy gale at Poldhu brought the masts crashing down. Marconi responded to this disaster—his first major setback—with great resilience, at once setting Kemp to work on clearing the wreckage and erecting a substitute aerial of simpler but more stable design; this was ready for testing within about a week. Inevitably it was electrically inferior to the original aerial, and Marconi decided to cut his losses and settle for one-way communication from Poldhu to Newfoundland—the nearest landfall in North America. On November 27th 1901, he set sail with two assistants, Kemp and Paget, taking a stock of kites and balloons as their sole means of supporting a receiving aerial. Just before departing, they learned that the aerial at Cape Cod had met with the same fate as the original Poldhu aerial. One of its masts had landed within a metre of Vyvyan, who had earlier questioned its safety.

Success against all odds

Arrived at Newfoundland, Marconi made himself known to the Governor, who put an empty building at his disposal, and gave out that he was making routine observations of ship-to-shore reception.

10 Raising a kite-aerial for transatlantic reception tests at St. John's, Newfoundland, in December 1901; Marconi is on the far left

He then cabled Poldhu to begin the transmission of the Morse letter 'S' for three hours each day. This letter ('dot, dot, dot') was chosen partly for ease of recognition, but also because the transmitter could not be trusted to transmit dashes without breakdown.

The weather was bad, and on the first day of tests attempts to raise an aerial ended in the loss of one of the balloons. On the next day, December 12th 1901, the wind was even stronger, and soon a kite was lost. A second kite fared better, but its violent plunging and rearing varied the electrical capacitance of the aerial too rapidly to allow a tuned receiver to be kept on tune, and forced Marconi to revert to an untuned circuit. He used a so-called 'self-restoring coherer' as his detector. This was not in fact a coherer at all, but an early example of a detector operating (as modern detectors do) by rectifying the radio-frequency signal, thereby converting its fluctuations to audio frequency. It was used in conjunction with a sensitive telephone, and thus allowed Marconi to listen for a faint but rhythmic series of dots through the random crashing of naturally occurring radio noise ('atmospherics'); the use of the ear to discriminate against noise was quite impossible with a coherer.

At 12.30 pm Marconi was at last convinced that he could pick out the signal, and handed the earpiece over to his companion. 'Can you hear anything, Mr Kemp?', he asked. Kemp confirmed that faint but unmistakable signals could indeed be heard, and Marconi's notebook records 'Sigs at 12.30, 1.10, and 2.20'.

The next day the weather was even worse, and it was evident that there

11 Transatlantic tests, 1901; Marconi with apparatus

12 Transatlantic tests, 1901; Marconi with his assistants Kemp (left) and Paget

was no immediate prospect of continuing the tests. Marconi therefore decided to release the news of his achievement, though he was aware that with no instrumental record to offer, nor even confirmation by an independent observer, he was in a weak position to substantiate such a sensational claim.

Public reaction was, of course, enthusiastic, but in the scientific community many considered that Marconi's ears had deceived him, though few doubted his honesty. The telegraph company operating in Newfoundland at once asserted its monopoly by threatening legal action if the tests continued, thus denying Marconi any chance of confirming the observations. Two months later, however, he rigged an outsize aerial on a westbound transatlantic liner and was able to maintain night-time reception of messages from Poldhu to a range of nearly 2,500 kilometres, under conditions that left no room for doubt.

The anti-climax

Marconi was, nevertheless, still a long way from being able to offer a

reliable transatlantic service. A permanent station was established at Glace Bay, Cape Breton Island, on the east coast of Canada, and tests were undertaken with Poldhu and with the station at Cape Cod. But propagation was so capricious that it was impossible to assess with any confidence the effect of experimental changes in the circuitry or the aerial configuration. Moreover, to maintain public confidence it was essential to keep up a token flow of transatlantic messages for publication, and this diverted effort from experimental work, especially as a message often had to be repeated over a period of many hours before it was finally received. In March 1903 the Company was persuaded by *The Times* newspaper to inaugurate a limited news service, but this ended after nine days when ice brought down the aerial at Glace Bay.

It gradually became clear that consistently better results were obtained when the wavelength was increased. The wavelengths already in use were of the order of two thousand metres, long by today's standards, and the only way to make efficient use of still longer wavelengths was to erect even bigger aerials. It was decided that, until this could be done, the Glace Bay and Poldhu stations should be used to earn some revenue for the Company by providing a long-range news service for transatlantic liners.

The growth of marine radio

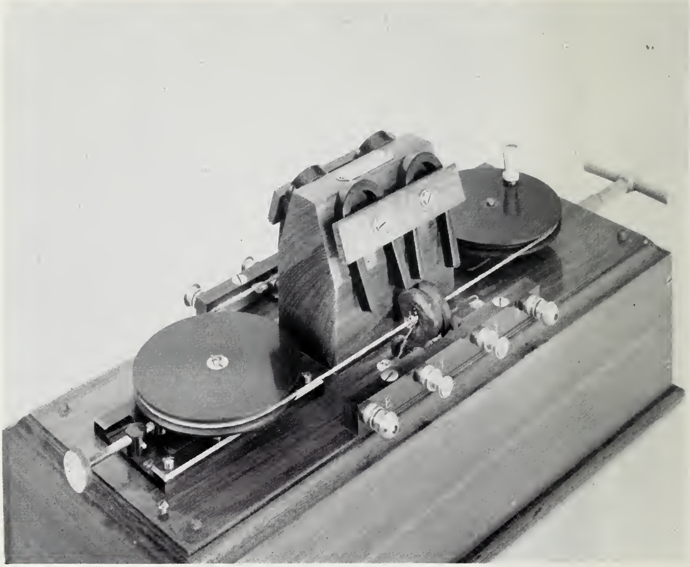
It had always been accepted as inevitable that mariners should be helplessly isolated once their ship lost sight of land. Now, the range and certainty of radio communication offered hope of ending this situation.

The first commercial installation on a merchant ship was in 1900, when untuned Marconi equipment was fitted to the German liner *Kaiser Wilhelm der Grosse*. By the end of 1902 seventy ships had been equipped and there were twenty-five land stations for their use, including several on the east coast of North America.

The Company now installed receivers incorporating a detecting device that was radically different from the coherer, offering higher sensitivity, faster signalling speeds, and better discrimination against interference. This was the 'magnetic detector', developed by Marconi from an experimental detector invented by Rutherford in 1895, which in turn depended on a phenomenon demonstrated by Henry in 1842. Much as tapping the face of a barometer overcomes stickiness in the movement and frees it to take up a true reading, a high frequency acting on a piece of magnetic material overcomes its magnetic 'stickiness' (hysteresis) and frees it to respond to its magnetic environment.*

In Marconi's magnetic detector, an endless band of iron wires is moved by clockwork past permanent magnets at about eight centimetres per second. At the point where the moving band experiences a strong field

* This effect is used in modern tape-recorders, where a high-frequency component is added to the current in the recording head.



13 Marconi magnetic detector

from the magnets it is surrounded by two small coils of wire; one coil carries the radio-frequency signal from the aerial, the other is connected to headphones.

The signal received from a spark transmitter consists of separate bursts of radio-frequency current, recurring at audio frequency. As each burst occurs, wire that has entered the coils since the previous burst responds to the magnets, inducing an impulse of current through the headphones, and the rapid succession of such impulses gives an audible note. Affectionately known amongst operators as the 'Maggie', this device was in widespread use for nearly twenty years.

Commercial rivalry and official control

Marconi's Marine Company did not sell its equipment, but charged a rental that also included the services of a trained operator and the use of Marconi shore stations; since no direct charge was made for individual messages, there was no infringement of the Post Office's monopoly of communication. However, this arrangement enabled the Company to restrict use of their shore stations to ships carrying Marconi apparatus,

since these ships alone were paying for the stations; an exception was made only in the case of distress calls. Marconi's large network of strategically placed shore stations therefore constituted a very strong incentive to ship owners to install Marconi equipment, and this fact was greatly resented by competitors. Operators on Marconi-equipped ships were also barred from communicating with ships carrying competitors' equipment, even withholding from their own captains messages picked up from alien vessels unless these were specifically demanded, and there were allegations that they indulged in deliberate jamming. The Company's attempts to preserve its dominant position should, however, be judged in the context of the general state of anarchy that characterized the development of radio at that time.

Marconi's chief competitor was the Telefunken Company, an amalgamation of Germany's radio interests enjoying strong governmental support, and it was Germany who, in 1903, called an International Wireless Telegraphy Conference, at which the desirability of unrestricted communication ('intercommunication') was a key issue. It was not until 1912, however, that the Marconi Company finally conceded full intercommunication.

On January 1st 1905, radio communication in Britain came under the provisions of the Wireless Telegraphy Act of 1904. The purposes of the Act were to bring radio under governmental control for strategic purposes, to enable the government to enforce international agreements, and generally to ensure that the radio spectrum, as an important new natural resource, was developed for the public good. All stations were to be licensed, and the Marconi Company's shore stations were granted licences for eight years (though the Post Office were in fact to oblige the Company to sell the stations to them in 1909). Telegraph messages to and from ships at sea ('Marconigrams') could be relayed through the inland telegraph network.

The need for effective control of radio transmissions was illustrated by an incident that occurred in London in 1903. Marconi's progress in achieving effective tuning had been undeniable, and numerous demonstrations had established that stations using different wavelengths could operate in close proximity without mutual interference. However, the Company also implied that tuning enabled them to offer communication that was secret and proof against interference, and one enterprising critic decided to demonstrate that such was not the case. This was Neville Maskelyne, son of the famous illusionist, and himself professionally connected with Marconi's competitors. By means of a transmitter on the roof of the Egyptian Theatre, Piccadilly (which was owned by his father), he was able to interfere with a demonstration being staged nearby at the Royal Institution. Professor Ambrose Fleming was giving a lecture which was to culminate in the reception of a ceremonial message from Chelmsford. During the lecture his assistant, receiving test signals, was alarmed to find

that the telegraph printer connected to the output of the receiver was producing such messages as 'Rats' and 'There was a young fellow of Italy, who diddled the public quite prettily. . . '. The interference ceased just before the actual demonstration took place, but Maskelyne made sure that the episode received extensive publicity.

Press comment at this period tends to depict Marconi as an innocent, whose well-deserved reputation for integrity was being undermined by his Company's commercial policies.

Marconi himself made no such distinction, however. On one occasion Kaiser Wilhelm II, seeking to excuse noticeable coldness towards Marconi at a public dinner, said to him: 'Signor Marconi, you must not think I have any animosity against yourself. It is the policy of your company I object to.' Marconi replied 'Your Imperial Majesty, I should be overwhelmed if I thought you had any personal animosity against me. However, it is I who decided the policy of my company.'

Marconi marries

If Marconi was not altogether the disinterested scientist, he most certainly was not the ruthless tycoon, and his personal popularity was considerable.

Through his modest and abstracted bearing could be glimpsed great determination and self-confidence. This conformity to the ideal of the 'strong, silent man' combined with the glamorous nature of his achievements to make him a highly eligible bachelor, and twice he became engaged to American girls encountered during his innumerable Atlantic crossings. When he eventually married, however, in 1905, it was to a nineteen-year-old Irish girl, Beatrice O'Brien ('Bea'). Her family, though impoverished, were of the Protestant nobility, and regarded Marconi's fame and potential fortune as poor compensation for his being a commoner and, worse, a foreigner (though happily not a Catholic).

The transatlantic service

During the winter 1904–5, the Glace Bay station in Nova Scotia was moved, in bitter weather, to a new site some nine kilometres distant, at which a larger aerial could be erected. The original 'inverted cone' aerial, supported by four 64-metre towers, was now surmounted by an umbrella roof 615 metres in diameter, with provision for extension to 885 metres. In May 1905 Marconi arrived with his bride at this remote and inhospitable outpost, installed her in a small house with Vyvyan's wife, and threw himself into his work, oblivious of the fact that the two women did not get on; it was Bea's introduction to an aspect of Marconi's character that was to contribute to the decline of their marriage.

Marconi supervised the tuning of the station, then set off for England (leaving Bea behind), to test reception on the voyage. The daylight range achieved was 2,900 kilometres, which was a substantial increase but still not enough, and subsequent tests with Poldhu showed no promise of

14 Directional experiments with long horizontal wires, off Poldhu. Cork floats supporting an aerial can be seen trailing aft. Marconi is near the tiller, Kemp listens with headphones

further improvement. At this crucial stage, Marconi made a timely discovery. Working at Poldhu, he noticed that an aerial wire lying on the ground received more strongly when its free end pointed away from the transmitter. This chance observation led him to develop an inverted-L configuration (with the horizontal arm much longer than the vertical) which was markedly directional. A cable was sent to Glace Bay, instructing that three quarters of the umbrella should be lowered, leaving in position the quarter furthest from England. As expected, the signal at Poldhu became much stronger.

This characteristically empirical invention, patented in July 1905, was not merely directional, but also radiated (or received) very long wavelengths more efficiently than previous aerials, and became the Company's standard form of aerial for long-range work. It was now decided that the Poldhu site was too small to accommodate a large directional aerial, and a new site was chosen at Clifden in the west of Ireland. Here, Marconi built a station wielding the unprecedented power of three hundred kilowatts. The site was remote, and at some seasons the boilers were fired by peat cut from the bog; the only vehicular access to the station was by the Company's own light railway. The scene was dominated by a building over one hundred metres long which housed the air-spaced capacitor on which the high-voltage power was momentarily stored before being discharged through the aerial transformer.

For the Clifden station, and the sister installation of Glace Bay, Marconi

15 The main capacitor at the Clifden station under construction, about 1906. The generous air space between the galvanized steel sheets ensured reliable operation at about 80,000 volts, but 1,800 sheets were needed to attain the required capacitance of 1.16 microfarads

directed his inventive powers towards a most important circuit element that had hitherto undergone little improvement—the spark itself. The spark, once struck, stayed conductive throughout the radiation of each wave-train, during which time (in accordance with the mathematics of loosely coupled circuits) the oscillations transferred themselves from spark circuit to aerial circuit and back again several times. As a result, energy that

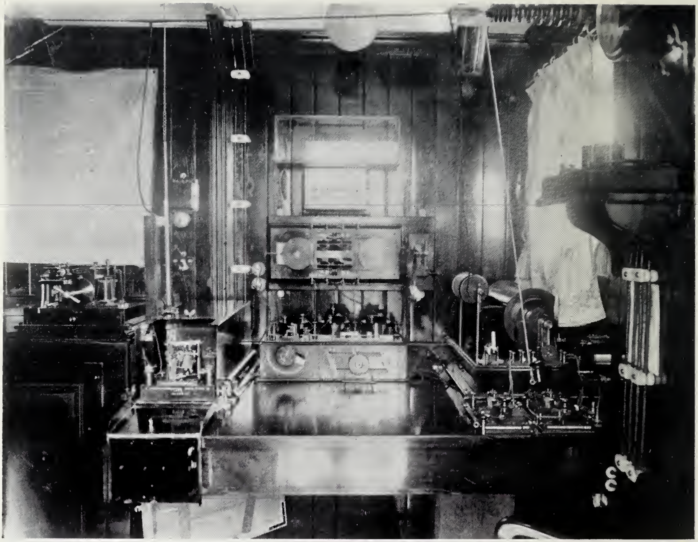
should have been radiated from the aerial was dissipated in the spark, whilst the aerial oscillations, instead of decaying smoothly, rose and fell in magnitude; this broadened the spectrum of radiated frequencies, thereby defeating the object of selective receivers and worsening interference with other stations. Moreover the recurrence of the spark, and hence of the wave-trains, was slow and erratic, producing in the receiver's headphones a growl of indeterminate pitch difficult to pick out from atmospherics and interfering signals.

Marconi now made the spark strike and extinguish in a regular and controlled manner by arranging for the rotation of a studded steel disc to vary the length of the spark gap. As each stud came opposite a stationary electrode, the gap narrowed and the spark struck; as the stud moved on, the gap lengthened and the spark was extinguished. In consequence, the received signal acquired a distinct musical pitch. Moreover, the extinction of the spark was timed to occur just when the oscillations had transferred to the aerial circuit for the first time; being unable to transfer back to the now non-existent spark circuit, they decayed slowly and smoothly as energy was radiated by the aerial, with consequent narrowing of the radiated spectrum.

The combination of the directional aerial and this 'disc discharger' improved performance to the point where Marconi at last felt confident that he could offer a commercial transatlantic service, and this was opened in October 1907, nearly six years after the first experimental transmission. Within three months some 100,000 words had been transmitted, but at times messages were seriously delayed. The Company attributed this to congestion and unreliability of the long land-lines linking the stations to London and New York respectively. However, one of Marconi's keenest rivals in America, R. A. Fessenden, unsportingly monitored the transmissions over a period of two weeks and reported (in a letter to *The Electrician*) that messages were sometimes repeated six times before finally being received satisfactorily, and that the effective rate of signalling was only three words per minute, as against the Company's claim of twenty.

Business problems

At this period the Company's finances were particularly precarious. A letter to Marconi from the Managing Director of the Company ended: 'I am extremely busy. Half my time is taken up in very unsuccessful attempts to get money, and a great part of what is left in seeing how we can do without it.' When R. N. Vyvyan visited South Africa in search of business it was on the understanding that he would have to pay his own expenses unless he returned with orders (which he did), whilst a less senior colleague, H. J. Round, wrote to his parents regretting that he could not visit them because his wages were not being paid; these tactics could not be applied to the factories' workers, and 150 of them were dismissed. Marconi himself put all the money he possessed into the Company to keep it running.



16 The radio cabin on S.S. Lusitania, *1907. A passive tuner (centre) coupled the aerial to the magnetic detector (above). The induction coil used in the emergency transmitter can be seen on the right; on the left are a coherer receiver and a Morse inker. The $1\frac{1}{2}$-kilowatt main transmitter is housed in a separate compartment (not shown), to minimise the noise from its spark and its rotary-converter power supply*

In 1908 the Managing Director resigned, and as an emergency measure to restore public confidence Marconi took over the position, but he had no taste for executive responsibility, and in 1910 he engaged a successor, Godfrey Isaacs, who had financial experience and connections to offer but no knowledge of radio. From the outset, it was a brilliantly successful appointment, and Isaacs' imaginative, aggressive policies dominated the Company for many years. Within a year or two of taking office, he successfully undertook litigation to enforce the Company's patents, which were being violated with impunity by competitors, and he largely resolved, to the benefit of both companies, the commercial conflict with Telefunken that had increasingly been blighting Marconis' overseas business. A less satisfactory situation arose when, in 1911, Sir Oliver Lodge was granted an extension of his 'tuning' patent of 1897, thereby threatening Marconi's key 'four sevens' patent. The Company paid Lodge £18,000 for his patents and appointed him as a scientific adviser.

Two events brightened Marconi's personal life during these stressful

years; in 1908, Bea gave birth to a daughter, Degna, who was many years later to write an affectionate and revealing biography of her father (Bea's first child had died when only a few weeks old). And in 1909 came a recognition that must have been especially piquant to a man who, ten years before, had been patronisingly dismissed by the scientific establishment as a mere entrepreneur; Marconi was awarded the Nobel Prize in Physics. By a further stroke of irony, the prize was shared with Professor K. F. Braun (famous as the inventor of the cathode-ray tube), one of the founders of Telefunken.

When Marconi handed over to Isaacs in 1910, he returned to his position as technical director, but his role was now changing. By this time, radio techniques were becoming too diverse for one man to retain the unique position of technological pre-eminence that Marconi had occupied for so long. The very successs of his spark devices deterred him from investigating the oscillatory arcs and high-frequency alternators that were to provide the next generation of high-power transmitters. Nor did he contribute to the development of the three-electrode valve, which was shortly to overturn the whole structure of radio technology, though his Company held the patent for the device that was arguably its precursor—Fleming's two-electrode 'oscillation valve' of 1904. Fortunately he had engineers (notably H. J. Round) whose expertise ensured that the Company was not left behind in this new development. Marconi still determined the technical policy of the Company, and still had important innovations to contribute to the advance of radio, but thenceforward it was to be as the driving force behind a team of specialists rather than as an individual experimenter.

The Imperial Wireless Scheme; The Marconi Scandal

In 1910 the Marine Company paid a dividend for the first time, after ten years of existence, and the number of Marconi-equipped ships increased during the year from 143 to 250; this made it easier for ships in mid ocean (still unable to communicate directly with shore stations) to have their messages relayed by other ships within range, whilst meteorology was beginning to benefit from ships' weather reports.

Though marine applications continued to be the mainstay of radio, the opening of the transatlantic service had shown that radio could now offer an alternative to cable telegraphy for long-distance point-to-point communication. An obvious application was to build a network of stations that would link the entire British Empire, and in March 1910 the Marconi Company submitted proposals for such an 'Imperial Wireless Scheme' based on eighteen stations, which the Company would build and operate. The traffic rates would be half those charged by the cable companies, whilst the stations would be of great strategic value; overland telegraph lines crossed foreign territory, and submarine cables could easily be cut by hostile warships. Moreover, world-wide communication with ships of the Royal Navy would be achieved. The Government was critical of the

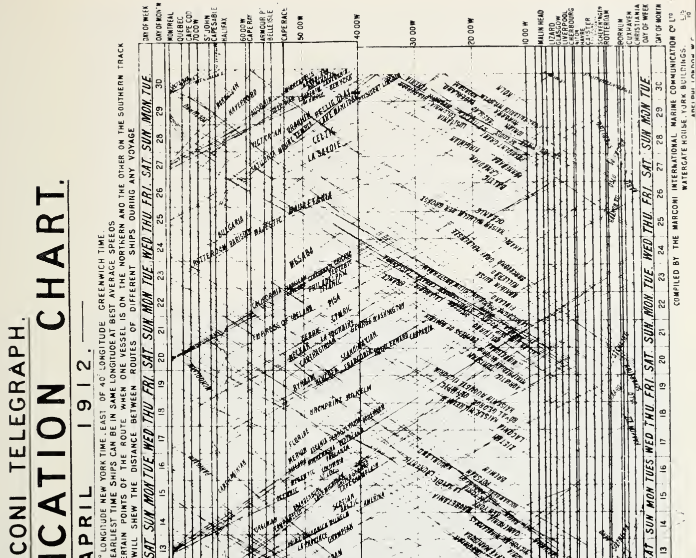
proposals, as conferring a monopoly upon a commercial company, but was under strong pressure from the Imperial Defence Committee to provide radio communication. Examination of all the possibilities showed the Marconi Company to be the only acceptable agency for constructing the stations, and in 1912 a contract was negotiated, but only for the first six stations; they were to be state-owned, with the Company collecting a royalty on receipts.

This contract was never finalised. While it was awaiting ratification by the House of Commons, rumours that had been circulating in the City erupted into a major furore that became known as 'The Marconi Scandal'. Accusations were made in the Press that the contract had been corruptly negotiated and that Government ministers had used their privileged knowledge of its impending completion to speculate in Marconi shares. A Select Committee appointed to investigate the affair concluded, after prolonged inquiry, that the first accusation was completely unfounded, and that the ministers had been guilty only of indiscretion, though their subsequent behaviour had been lacking in frankness. At no time during this unedifying affair was Marconi's own integrity in question, and he was extremely bitter over having his name constantly associated with it. A new contract for the six stations was signed in July 1913, but none had been completed by the time war broke out in August 1914, and the project was abandoned.

The scandal was only one of the events that crowded in upon Marconi during 1912. In January, Godfrey Isaacs put before the Board the proposal that an ambitious new factory should be built at Chelmsford; he further suggested that the work should be completed in time for the factory to be seen in operation by the delegates to an International Radio-telegraphic Conference due to open in London less than six months later. This extraordinary deadline was duly met, and a new London office opened in the interim.

When the Conference met, it devoted much attention to the deficiencies in current practice that had been revealed by the loss of the *Titanic* less than three months previously. The world's greatest liner, she struck an iceberg in mid-Atlantic on her maiden voyage, and sank in less than three hours. Though radio secured the rescue of the 700 survivors, many of the 1,500 who died would have been saved if the ship nearest to the liner had picked up her distress calls. But this ship carried only one radio operator, and he had just gone off duty after a sixteen-hour watch. Further, the distress calls stimulated a flood of uncontrolled radio messages that jammed the ether for hours, and prevented reliable news from reaching shore. Giving evidence at the Board of Trade inquiry into the disaster, Marconi put forward the idea of an unmanned 'auto-alarm' that would ring a bell on receipt of a suitably specified distress signal, and in 1920 the Company successfully demonstrated such a device; auto-alarms later became mandatory for certain classes of shipping.

Marconi and Bea had both been invited to be guests on the *Titanic*'s



17 Each month, a chart was issued showing Atlantic crossings of Marconi-equipped ships, so that operators would know what ships would be within their range at any time. Note the entry for the Titanic, *sailing from Southampton on April 10th*

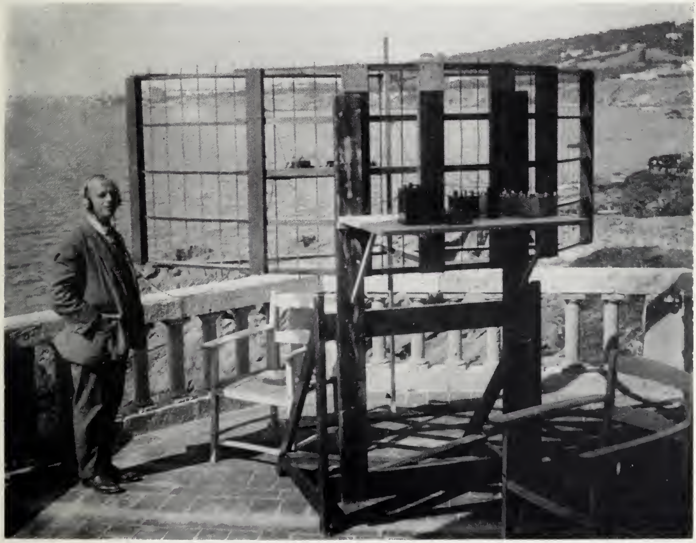
maiden voyage. He had transferred to an earlier sailing for business reasons, but Bea had accepted the invitation, expecting to join him in New York. Then, at the last moment, her two-year-old son was taken ill, and she reluctantly cancelled her passage. Their marriage was at a low ebb at this period, and later in the year they were persuaded that a motoring holiday together might help matters. They chose Italy, where Marconi visited the high-power station he had erected, capable of communication with Italian Eritrea nearly 4,000 kilometres away. Then, *en route* from Spezia to Genoa, they had a head-on collision with another car. Marconi's right eye was injured beyond redemption and had to be removed, and he

18 Marconi (centre) in the trenches during the 1914–18 war

only regained the sight of the left eye after an alarming interlude of total blindness.

The first World War

In July 1914, Marconi was honoured by Britain, receiving from King George V the honorary title of Knight Grand Cross of the Royal Victorian Order; within a few weeks, the outbreak of war had transformed him into an alien whose movements were restricted. Italy, though diplomatically bound to Germany and Austria, was neutral, and after a time Marconi was allowed to move to Rome, where he took his seat in the Senate; he had been appointed a Senator in the spring of 1914 on reaching the minimum age limit of forty. When Italy entered the war on the Allied side, in 1915, he at once joined her armed services as an adviser on radio communication, first as a Lieutenant in the army, later as a Lieutenant-Commander in the Navy. His most significant work was carried out in 1916, in conjunction with one of his senior engineers from the Company, C. S. Franklin. In order to relieve congestion of the normal wavebands, which was hampering naval communications in the Mediterranean area, they established a system of communication on a wavelength of about two metres, using a spark in



19 C. S. Franklin with an ultra-short-wave aerial, 1916

compressed air. This part of the spectrum had not been used since the experimental days of nearly twenty years before, being able to provide only 'line-of-sight' range. However, for working between warships this range was still useful, whilst the ability to confine communication within narrow beams by means of reflectors gave a measure of security and minimised interference.

Other Marconi engineers attached to the armed services were also responsible for important advances in technique. Radio telephony equipment was developed for use in military aircraft, thereby laying the foundations of post-war radio-telephony equipment for civil aviation and for broadcasting. Captain H. J. Round, making use of patents bought by the Company in 1911, used valve receivers to bring radio direction-finding to an unprecedented degree of sensitivity and precision; German warships, not suspecting that they were within range of British direction-finding stations, used their radio freely, enabling their positions to be plotted. The Battle of Jutland was joined because the Admiralty correctly concluded that the German fleet was about to put to sea, on the strength of a measurement showing a change in bearing of less than one-and-a-half degrees.

The work on ultra-short waves by Marconi and Franklin has an obvious bearing on the subsequent evolution of microwave communication. But it also led Marconi to the more general conclusion that radio engineers had got into a rut by confining all experimental work to long waves, and that the wavelengths below two hundred metres, hitherto dismissed as commercially useless, merited systematic investigation.

During the last two years of the war and the first year of peace, Marconi was largely engaged in representing Italy abroad. When America entered the war in 1917, he was sent across as a member of a good-will mission, by virtue of his wide experience of the country and his great personal popularity; in 1918 there were two official visits to London, and in 1919 he was a delegate to the Paris Peace Conference.

He now took a step that was greatly to influence his life-style. He bought from the Admiralty a 700-ton steam yacht that had been in service as a minesweeper, had it luxuriously fitted out, and equipped it with a laboratory for radio experiments. The *Elettra*, as he named the vessel, enabled him to combine work and play, society and solitude, in a most agreeable manner.

The short-wave 'beam' system

In England, Franklin had been continuing the investigation of short waves. He had increased the wavelength to 15 metres, in order to be able to use a valve transmitter, and by using reflectors behind the aerials had transmitted speech from London to Birmingham with only 700 watts of power. Concurrently, his colleague H. J. Round was experimenting with waves of 100 metres, and amateur experimenters were using a variety of wavelengths below the 200-metre upper limit imposed upon them. From

20 *Marconi's laboratory on the* Elettra

all quarters came reports that short-wave signals were sporadically being received at ranges much greater than those achieved regularly. Marconi decided that extensive data was required in order to elucidate these exciting observations, and that the *Elettra* offered an ideal means of collecting it.

An experimental transmitter operating at 97 metres was built at Poldhu, with a large parabolic reflector beaming the signal in a south-westerly direction, and in April 1923, Marconi set out to investigate reception. He found that as range increased the signal strength first fell off rapidly, then recovered, and that at the furthest point of *Elettra*'s voyage, four thousand kilometres away, night-time signals from Poldhu's short-wave transmitter were stronger than those from high-power long-wave transmitters elsewhere in Britain, even when Poldhu's power was reduced to one kilowatt. Over the next twelve months, further tests at similar wave-lengths established that night-time signals from Poldhu could be received in North America, and that good signals were reaching Australia at certain hours.

These spectacular results were achieved at a time when Government attempts to plan an Imperial Wireless Scheme, revived soon after the war, had reached a complete impasse, three successive committees having failed to devise a formula that could reconcile the conflicting interests of the Post Office and the Marconi Company. In the absence of agreement, the Post

Office were constructing a high-power station that would avoid infringement of the Company's patents, whilst Marconis' were contracted, through overseas associates, to supply stations in Australia and the Union of South Africa; all, of course, were to use long waves.

The Company now decided, with an audacity in the best Marconi tradition, to approach the Government with proposals to link the Empire by means of short-wave stations in England, Canada, India, South Africa and Australia, having obtained agreement from the last two countries to drop the planned long-wave stations. Because the stations would use highly directional aerials, the scheme was named the 'beam' system. The potential advantages of short waves were considerable. The stations would be of relatively low power (20kW), and hence much cheaper to build and operate than long-wave stations, whilst the gain in the reliability of communication promised to outweigh the disadvantage of limited hours of communication within each 24-hour period. However, to ensure the Government's agreement the Company had to offer a contract in which they themselves bore all risk of failure, and these risks were immense. All guarantees of performance had to be made in terms of the only band of wavelengths (100 metres) that had been investigated, though this band is in fact less suitable for long-range communication than the shorter wavelengths that the Company had yet to explore. Transmitters, receivers, feeders and aerials had to be designed, to tight schedules, for operation at frequencies that presented entirely new problems.

The contract was quickly agreed, and work went ahead, while Marconi set out on the *Elettra* for a further series of tests to investigate the propagation of various wavelengths down to 32 metres. It was found that the shorter wavelengths permitted long-range communication during daylight, and provision was made to exploit them in the 'beam' stations, though of course this entailed a proportionate increase in the operating frequencies of the equipment.

Happily, Franklin was an outstanding engineer, and responded to the challenge by designing equipment that was to stand the test of time; over forty years later the Science Museum, seeking to acquire one of his original transmitters, had to wait until it could be released from service! Vyvyan, now the Company's Chief Engineer, saw to it that Franklin's designs were built, delivered and installed on time.

As the stations came into commission, it became evident that the beam system was a brilliant success, and that Marconi's vision of world-wide radio communication had finally been realised. He could himself lay claim to a good share of the credit; it was he who had seized upon the significance of the original, rather minor, project with two-metre waves, vigorously followed it up, and borne much of the responsibility for the final gamble. The execution of the scheme had been inspired by his quiet, confident leadership.

The years 1920–23, when the foundations of the beam system were being

laid, were also the years during which the Marconi Company played a leading role in establishing British broadcasting. Marconi himself took practically no part in this project, probably because he found the technical problems presented by broadcasting to be rather pedestrian when measured against the high adventure of the short-wave enterprise.

Marconi's last years

On a personal level, the early 1920s were troubled years for Marconi. In 1923, after much soul-searching, he concluded that it was his patriotic duty to join Italy's Fascist Party. Mussolini, for his part, was happy to have the support of a celebrated compatriot who was so universally respected, and made a great fuss of him. Marconi's public advocacy for the regime continued to the end of his life, though eventually he experienced misgivings, telling his daughter that it was no longer any use trying to talk to Mussolini, who would listen only to what he wanted to hear.

In 1924 Marconi's marriage finally broke up, and two years later he decided to marry an Italian girl, Cristina Bezzi-Scali. She was a Catholic and, moreover, the daughter of a Vatican official, so Marconi's status as a divorcee seemed an insuperable obstacle. However, he applied to the situation the resourcefulness and persistence that had served him so well in his professional life. With Bea's co-operation, he established that they had embarked upon their marriage with mental reservations sufficient to justify the ecclesiastical courts in annulling it on grounds of 'defective intention'. He and Cristina were married the following year; in 1930 a daughter was born, and given the name 'Elettra'.

The last ten years of Marconi's life were clouded by heart attacks, and much of his time was taken up with the social life of an international celebrity. But though his involvement with the work of the Company decreased he never retired, and the early 1930s brought a resurgence of scientific activity. He returned to the study of very short wavelengths, for which valve generators were now available. It was found possible to design apparatus for two-way telephony over 'line-of-sight' distances, using a wavelength of fifty centimetres, and in 1932 a permanent connection was established over a range of twenty-four kilometres. The circuit linked Vatican City to the Pope's summer residence at Castel Gandolfo; Marconi had become a Catholic shortly after his second marriage, and had subsequently given his personal supervision to the installation of a short-wave broadcasting transmitter in the Vatican.

Predictably, Marconi was not content to accept that waves of under a metre in wavelength would be limited to line-of-sight ranges. Once more, *Elettra* set off to explore the maximum range of communication, and once more Marconi showed that established theory was incomplete. Sporadic reception was recorded to over twice the line-of-sight range, thereby anticipating the development of 'scatter' modes of communication in the years after the 1939–45 war.

21 Marconi (in high silk hat) with Pope Pius XI at the inauguration, in 1933, of the ultra-high-frequency radio telephone link between the Vatican and the Papal summer residence

22 Marconi, his second wife, Cristina, and officials on the bridge of Elettra *in 1934, during demonstrations of a radio beacon operating at a wavelength of sixty centimetres*

Marconi had a fine sense of 'theatre', and he used it to good effect in staging what was to be his last major demonstration, in the summer of 1934; appropriately this was concerned with the improvement of safety at sea. *Elettra* steamed into harbour at normal speed, her helmsman guided solely by the beam of an ultra-high-frequency beacon installed on the cliffs. And to prove the point, Marconi had all the windows on the ship's bridge totally obscured.

Shortly after these experiments, Marconi had several heart attacks, and it became evident that only a drastic reduction in his activities could save him. He refused to co-operate, and insisted on returning to an active life after each illness. Late in 1935 he embarked on a last diplomatic assignment for Italy, travelling to Brazil with the unenviable mission of defending the Abyssinian war. Visiting London on his way back, the man who had made broadcasting possible suffered the ultimate humiliation of being told by Sir John Reith, Director General of the BBC, that he could not be allowed to broadcast to the British people in defence of Italy's action.

Marconi died in Rome on July 20th 1937, aged 63. Of the many tributes paid to him, one of the most memorable was also the most fleeting. He had

23 Marconi, with Cristina and their daughter, Elettra, leaving a London nursing home

caused the empty ether to be filled with the clamour of human affairs; at an agreed time on the day after he died, that clamour was briefly stilled as radio transmitters all over the world closed down for two minutes.

The Marconi Company has continued to prosper, and is now a major supplier of a wide range of products, many of them undreamed of in Marconi's lifetime; since 1968 it has been part of the General Electric Company, but a discernible identity survives, especially at Chelmsford, where extensive and well-organised archives recording Marconi's work and the history of his Company are maintained for the use of scholars.

Marconi's stature

At the outset, Marconi seemed commonplace enough—a dreamy, ignorant youth with a presumptuous, half-baked ambition—and it is undeniable that he chanced upon an exceptionally favourable situation, with most of the essentials for wireless telegraphy already at hand. But to belittle his achievements on this account is to ignore two pertinent facts: many people were in a much better position than Marconi to demonstrate Hertzian waves as a potentially important medium of communication, but none of them did so; and no-one was able to catch up with him during the crucial years when he had established the feasibility of wireless telegraphy but had not yet begun to draw significant technological support from his assistants.

In later life, Marconi was remarkably resistant to the erosion of usefulness that can befall the ageing pioneer. He retained both his creative urge and his sound technical judgement, and though the personal charm that distinguished him as a young man was later marred by increasing aloofness, he never lost his ability to win great respect and affection from the engineers who worked with him.

He did not aspire to the disinterested pursuit of knowledge, and to that extent is perhaps ineligible to be considered a 'great scientist'. But in his single-minded devotion to what was practical he nevertheless made a great contribution to science, transforming radio from a lecture-room novelty into a central feature of modern life.

Further Reading

Marconi by W. P. Jolly (Constable, 1972)
A History of the Marconi Company by W. J. Baker (Methuen, 1970)
My Father, Marconi by Degna Marconi (Muller, 1962)

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